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REGULATORY CRITERIA FOR THE DISPOSAL OF RADIOACTIVE WASTES

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ABSTRACT

Radiological protection criteria have been proposed by the Atomic Energy Control Board for judging the potential long-term impacts of radioactive waste disposal options in which the wastes are contained and isolated from the human environment. This paper reviews the proposed criteria and the regulatory guidelines for their application in performance assessments, taking note of the public comments received to-date.

RÉSUMÉ

La Commission de contrôle de l'énergie atomique a proposé des critères de radioprotection pour évaluer les incidences possibles à long terme des options pour l'évacuation des déchets radioactifs, selon lesquelles les déchets font l'objet d'un confinement et sont isolés de l'environnement. Le présent document examine les critères proposés et les lignes directrices pour leur application dans les évaluations de rendement, en tenant compte des observations du public reçues jusqu'à maintenant.

REGULATORY CRITERIA FOR THE DISPOSAL OF RADIOACTIVE WASTES

1. INTRODUCTION

During the last five years, the Atomic Energy Control Board has expended considerable effort in documenting its regulatory policies and requirements that are practised in administering the Atomic Energy Control Regulations. In the area of radioactive waste management the need for documented regulatory criteria has created special challenges in formulating a unified framework, particularly when addressing the so-called "long-term factor" associated with some waste types and management options. The situation is further complicated since a wide variety of radioactive waste types are produced in this country that require waste-specific and site-specific regulatory approaches to be developed. As a consequence, the ideal specification of overall performance-oriented criteria in a unified regulatory framework for waste management has been an elusive goal, while regulatory documents continue to be produced to address specific issues that have arisen as a result of various industry plans and programs.

Earlier this year the AECB published Consultative Document C-104 in which were proposed a set of basic objectives and quantitative radiological requirements concerning the post-closure, long-term factor in the disposal of radioactive wastes by containment and isolation methods (1). The document also provided guidelines for the application of the radiological requirements to assist proponents in conducting long-term performance assessments and preparing licensing submissions to the AECB. The need for C-104 arises from the increased emphasis being placed on developing and implementing permanent disposal solutions for all major types of radioactive waste and from the timing, in particular, of public environmental hearings for two projects that have become known as the Port Hope Area Waste Disposal Project and Concept Assessment for Nuclear Fuel Waste Disposal.

Before examining the main features of these new regulatory proposals, it is appropriate to review briefly other AECB regulatory documents on waste management to clarify their purposes and relationships with C-104.

2. OVERVIEW OF AECB CRITERIA FOR WASTE MANAGEMENT

In Canada, radioactive wastes are generally categorized into three groups - uranium mill tailings, low-level wastes and nuclear fuel wastes - and the AECB has found it convenient and necessary to develop criteria for each of these major waste types. The first set of formally proposed criteria was published in Consultative Document C-1 in 1981 to address the long-term aspects of uranium tailings management (2). The document was aimed at developing regulatory requirements and guidelines for the decommissioning of active tailings facilities near mine and mill sites. The criteria notably contained design performance standards for contaminant releases and surface gamma levels. These proposed standards were subsequently replaced in the current AECB draft guidelines by general references to individual dose limitation, the ALARA principle and to keeping contaminant releases after decommissioning below those during active operations (3). The current draft guidelines also reflect the experience gained in authorizing the decommissioning of several

tailings facilities, details of which are being presented later at this conference (4).

More recently, Consultative Document C-36 has been issued dealing also with the management of wastes from uranium and thorium mining and milling (5). This document provides a comprehensive description of the licensing process, regulatory requirements and guidelines for the siting, design, construction and operation of mine/mill waste management systems. Thus, C-36 is complementary to the current draft guidelines for tailings decommissioning. A paper based on C-36 is also being given at this conference (6).

For the management of low-level wastes, no formal criteria have yet been proposed by the AECB. However, a number of draft licensing documents were prepared in the 1970s concerning the siting, design, construction and operation of temporary storage facilities, a method of management that continues to be widely used by industry. While specific details of the AECB licensing process and of the licensing requirements may have evolved during the intervening years, the principles behind them are still valid and relevant to the on-going operation of low-level waste storage facilities.

One aspect of low-level waste disposal that has been pursued vigorously is the development of the de minimis dose concept for application to certain very low-level wastes. This subject was addressed in Consultative Document C-85 (7). In the specific context of C-85, de minimis wastes are those which do not require any special precautions to be taken on account of the radioactivity in them, and which can therefore be handled and disposed of in the same way as other wastes which are similar but non-radioactive. Not surprisingly, the de minimis waste issue continues to demand a great deal of explanation and discussion since other regulatory jurisdictions and interested parties less familiar with radioactive waste management are necessarily involved.

With regard to nuclear fuel waste disposal, the AECB has published Regulatory Document R-71 (8), after taking into account public comments on its precursor consultative version, and Consultative Document C-72 (9). The former document, R-71, specified general requirements for the concept of deep geological disposal of nuclear fuel wastes in plutonic rock and requirements for the assessment of the concept and for the assessment documentation. Notably, R-71 specified only a qualitative requirement for the post-closure radiological impact of a deep disposal repository, but clearly indicated that probability considerations would be a factor in numerical acceptability criteria that were, at the time, under development. Consultative Document C-72, which is still to be finalized, provides a set of qualitative geological criteria applicable to the siting of a deep disposal facility. Its purpose at the Concept Assessment phase of the Nuclear Fuel Waste Management Program is that it outlines the site characteristics that Atomic Energy of Canada Limited should be demonstrating the technological capability to determine.

3. AECB CRITERIA FOR RADIOACTIVE WASTE DISPOSAL

The purpose of C-104 is to outline the proposed regulatory basis for judging the long-term acceptability of radioactive waste disposal options by specifying quantitative radiological protection requirements that would apply to the post-closure phase. Since there are factors other than purely

radiological impact that must be considered in regulatory decision-making, these factors were also addressed in C-104 to the extent permitted by the AECB legislative mandate. Thus the position of the AECB respecting responsibility to future generations and environmental protection was given in qualitative terms, recognizing that certain aspects of these factors would require societal decisions and judgements by other appropriate regulatory bodies. It is intended that the basic regulatory requirements in C-104 would be broadly applicable to the disposal of uranium tailings, low-level wastes and nuclear fuel wastes by methods using long-term containment and isolation from the human environment. The proposed requirements were as follows, with no priority attached to their order of presentation:

"A. Burden on Future Generations

The burden on future generations shall be minimized by:

(a) selecting disposal options for radioactive wastes which to the extent reasonably achievable do not rely on long-term institutional controls as a necessary safety feature;

(b) implementing these disposal options at an appropriate time, technical, social and economic factors being taken into account; and

(c) ensuring that there are no future radiological risks to human health that would not be currently accepted.

B. Protection of the Environment

Radioactive waste disposal options shall be implemented in a manner such that there are no future radiological impacts on the environment that would not be currently accepted and such that the future use of natural resources is not impaired by either radioactive or non-radioactive contaminants.

C. Protection of Human Health

(1) Requirements in the Absence of Institutional Controls

For a disposal facility where long-term institutional controls are not required as a safety feature, the predicted radiological risk to individuals shall not exceed 1×10^{-6} serious health effects in a year.

(2) Requirements in the Presence of Institutional Controls

For a disposal facility where long-term institutional controls are required as a safety feature, the predicted radiological risk to individuals may exceed 1×10^{-6} serious health effects in a year:

(a) if this is compatible with the results of optimization considerations, and

(b) provided that the predicted radiological risk to individuals does not exceed that which is presently accepted from current operations involving the same wastes."

The intent of requirement A is to fulfill our responsibility to future generations by ensuring that the institutional, financial and radiological burdens that may be bequeathed are reasonable, equitable and no more severe than we would be prepared to accept ourselves. With particular regard to the use of institutional controls as a primary safety barrier in a waste containment and isolation system, their use beyond a few hundred years is not recommended. Disposal options which do not rely on the long-term continuity and effectiveness of institutional controls will therefore clearly be favoured by the AECB. However, it is recognized that for some waste types in a site-specific situation, such as uranium mill tailings that are produced in large volumes, there may be no realistic disposal alternative to the maintenance of institutional controls in the very long term. In these circumstances, industry and governments would have to do the best they can to protect future individuals.

Insofar as the timing of waste disposal is concerned, implementation will depend on many factors, not the least of which are the availability and public acceptability of suitable disposal sites and technology, the safety of continued interim storage and overall economics. Where disposal is deferred though, mechanisms must be established to cover the future financial costs associated with its implementation.

On the subject of environmental protection, the intent of requirement B is to confirm the AECB policy position concerning the assumption that is widely adopted in the radiation protection community that if humans are adequately protected then other living species are also protected, although not necessarily all individual members of a species. This view is not necessarily held by environmental agencies, environmental critics and others and is an example of other factors that would contribute to the overall decision on specific waste disposal options. Similarly, reference is made in the same requirement to the protection of natural resources, an issue the requirements for which are primarily the responsibility of appropriate regulatory agencies other than the AECB to specify. However, the intent in C-104 is to flag this point in a general way that would cover such environmental compartments as the air, ground and surface waters, soils, flora and fauna, as well as economically viable natural resources.

In specifying the requirement for long-term radiological protection, requirement C, the approach advocated is based upon an extension of the AECB regulatory framework that is currently applied in the licensing of nuclear facilities, including designated radioactive waste management facilities. However, in order to judge the acceptability of hypothetical exposures of individuals that are forecast using predictive mathematical modelling techniques, the quantitative requirement is expressed in terms of risk. For the purposes of C-104, risk is defined as the probability that fatal cancer or serious genetic effects will occur to an individual or his or her descendants. By this definition, risk is the product of the probability of exposure, the magnitude of the forecast dose and the dose-to-health effect conversion constant ($2 \times 10^{-2} Sv^{-1}$). In this way, the probability of exposures occurring as a result of various events and processes that may or may not

happen is explicitly taken into account in the regulatory criterion. The risk approach to criteria for radioactive waste disposal is generally consistent with that emerging in the international arena (10), (11), (12) and has already been formally adopted in the United Kingdom (13).

For disposal facilities where the ideal goal of avoiding long-term institutional controls is achieved, that is, a "walk-away" situation, the proposed limiting risk requirement is 10^{-6} serious health effects in a year. This risk level was chosen as it is a prudently small fraction of the risk associated with a dose of 1 mSv in a year, that is, the principal limit on effective dose equivalent recommended by the International Commission on Radiological Protection for lifelong continuous exposures. Selecting a value of 10^{-6} in a year allows for uncertainties in exposure scenarios and their consequences and avoids prejudicing future nuclear activities that might impact on the same individuals. The value is also consistent with the de minimis risk level proposed in C-85 for determining when certain very low-level wastes may be disposed of with no special radiological precautions. Thus, from the point of view of the receptor, the radiological risk from a designated disposal facility would be no greater than that from de minimis disposals.

However, for disposal facilities where long-term institutional controls are unavoidably needed and are in place to ensure that radiological risks are kept acceptably low, predicted residual risks greater than 10^{-6} in a year to members of the public may be accepted. These risks could arise, for example, from contaminant releases to the atmosphere and to ground and surface waters in the case of a near-surface disposal facility. Since the disposal facility would remain under continuing control during the post-closure phase, the situation is more akin to that during normal facility operations, although the type of controls needed should be passive rather than active. The conditions specified by which risks greater than 10^{-6} may be accepted for the post-closure phase are intended to ensure that design and decommissioning measures are taken such that the risks are nonetheless as low as reasonably achievable and in any case no greater than those to members of the public during the pre-closure phase. For the general case of uranium tailings management which often requires long-term institutional controls, requirement C(2) should be seen to be entirely consistent with the current draft guidelines for decommissioning (3).

4. APPLICATION OF THE RADIOLOGICAL RISK CRITERIA

In addition to specifying numerical radiological acceptance criteria for the long term, guidelines were also proposed in C-104 on several aspects of their application in performance assessments of waste disposal options. Again, with no priority attached to their order of presentation, the guidelines were as follows:

"A. Identifying the Individual Concern

The individual risk requirements should be applied to a group of people that is assumed to be located at a time and place where the risks are likely to be the greatest, irrespective of national boundaries.

B. Probabilities of Exposure Scenarios

The probabilities of exposure scenarios should be assigned numerical values either on the basis of relative frequency of occurrence or through best estimates and engineering judgements.

C. Timescale of Concern

The period for demonstrating compliance with the individual risk requirements using predictive mathematical models need not exceed 10,000 years. Where predicted risks do not peak before 10,000 years, there must be reasoned arguments that beyond 10,000 years the rate of radionuclide release to the environment will not suddenly and dramatically increase, and acute radiological risks will not be encountered by individuals.

D. Output From Predictive Modelling

Calculations of individual risks should be made by using the risk conversion factor of 2×10^{-2} per sievert and the probability of the exposure scenario with either:

(a) the annual individual dose calculated as the output from deterministic pathways analysis; or

(b) the mean value of annual individual dose from the distribution of individual doses in a year calculated as the output from probabilistic environmental pathways analysis.

In addition, where probabilistic environmental pathways analysis is used, the number of simulations predicting annual individual doses in excess of 1 mSv should not exceed 5% of the total number of simulations.

E. Optimization

For a disposal facility where long-term institutional controls are required as a safety feature and the predicted radiological risk to individuals is likely to exceed 1×10^{-6} serious health effects in a year, all known radiological and non-radiological factors should be considered in an optimization analysis."

In view of the definition of risk used in C-104, it is necessary to define the individuals to whom the criteria apply, to quantify the probabilities of exposure scenarios and to define the appropriate consequence estimate from predictive modelling. When considering hypothetical exposures in the future, the precise identification of critical groups and their lifestyles is not possible owing to the uncertainties in population distributions and in environmental evolutionary processes. However, application of the risk criteria to a group of people assumed to have present-day habits and characteristics and assumed to live where the risks are greatest should give reasonable assurance that the risk criteria will not be exceeded. While this approach tends to fix the location of the reference group, due account must be taken of the probability of the exposure scenario, whether this involves chronic release of contaminants and transport to the surface environment by groundwater or disruption of the disposal facility by inadvertent human activities.

Quantification of scenario probabilities is likely to be very subjective and will require expert judgement unless sufficient evidence exists from past and present experience to permit more objective estimates to be made based on recorded observations. For example, it may be possible, based on regional land-use records, to quantify the probability that undeveloped land will be subject to various forms of building construction and to the sinking of drinking-water or irrigation wells.

With regard to the appropriate consequence estimate from predictive modelling, annual individual dose is the consequence of primary interest that would then be used in conjunction with the probability of the exposure scenario and the dose-to-health effect conversion constant to arrive at risk in a year. While this procedure is quite straightforward for conventional deterministic performance assessments, the interpretation of deterministic analyses that use Monte Carlo techniques for selecting input parameter values from distributions is less clear. In C-104, it is proposed that in these cases the mean dose of the output distribution of doses should be taken as the single value representing the consequences from input parameter variation. This procedure would only be valid for a given exposure scenario at a time, such as chronic contaminant release and groundwater transport to the surface environment in which the conceptual model is held constant. Other distinct exposure scenarios with their own conceptual models would have to be treated separately. Since the use of Monte Carlo techniques coupled to deterministic analyses may produce dose distributions with high doses in the tail end, albeit with a low relative frequency, the significance of the tail values may be overlooked by calculating the mean of the distribution. An additional criterion was therefore proposed in C-104 to help distinguish between different output distributions of dose. While the additional criterion is somewhat arbitrary, it seeks to limit the fraction of simulations that result in doses in excess of a reference dose level, in this case 1 mSv in a year.

A further issue addressed in C-104 is the timescale for which the regulatory risk criteria apply. Again, this is a matter of judgement since there does not appear to be any satisfactory, objective way of limiting the time period over which performance assessments should be carried. Overall, taking into account the characteristics of the major categories of radioactive wastes, the options for their disposal and the increasing uncertainties in the predicted consequences as the time period for predictions increases, it is considered that 10,000 years is a reasonable maximum period for performance assessments. Indeed, for some waste types and disposal options it is recognized that much shorter time periods for predictive modelling are all that are necessary. On the other hand, in some situations it may be necessary to present reasoned argument that the performance of disposal facilities which satisfactorily meet the risk criteria will not suddenly deteriorate beyond 10,000 years in a way that could result in short-term non-stochastic radiological risks to individuals.

The final guideline on application of the risk critria in C-104 concerns the optimization analysis that should be conducted for those disposal facilities where long-term institutional controls are needed and the predicted risk to individuals exceeds 10^{-6} in a year. Without giving detailed guidance, it is recommended that broad analyses of a wide variety of radiological and non-radiological factors be conducted for different disposal options to help discriminate between them.

5. PUBLIC COMMENTS ON C-104

Consultative Document C-104 was published in April 1986 with the customary 90-day public comment period immediately following. Although the official comment period has closed and the analysis of comments received has begun, there have been seventeen responses to-date and more are expected. The responses are about evenly divided between industry, regulatory agencies, other government representatives, learned scientific societies and individual members of the public, with the overwhelming majority expressing general support for the regulatory proposals. The detailed criticism that has been offered is in the main most constructive and is of a nature that should facilitate the drafting of the final version as an R-document. This is scheduled for publication by the end of December, 1986.

6. CONCLUSIONS

AECB criteria for radioactive waste disposal have been formally proposed that embody the notion of radiological risk to individuals in the long-term, post-closure phase of disposal facilities. The publication of numerical criteria fulfills an earlier undertaking by the AECB to develop specific radiological acceptance criteria for nuclear fuel waste disposal and at the same time provides criteria for the disposal of low-level wastes and uranium tailings. Guidance on the application of the risk criteria in long-term performance assessments has also been given particularly on the nature of the consequence estimate from predictive modelling and the timescale of regulatory concern. The public comments that have been received are generally supportive of the regulatory proposals and will help their finalization on a timely schedule.

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